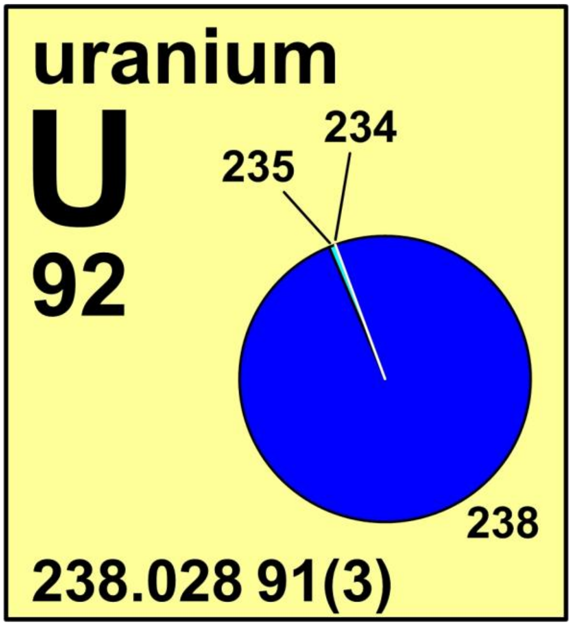
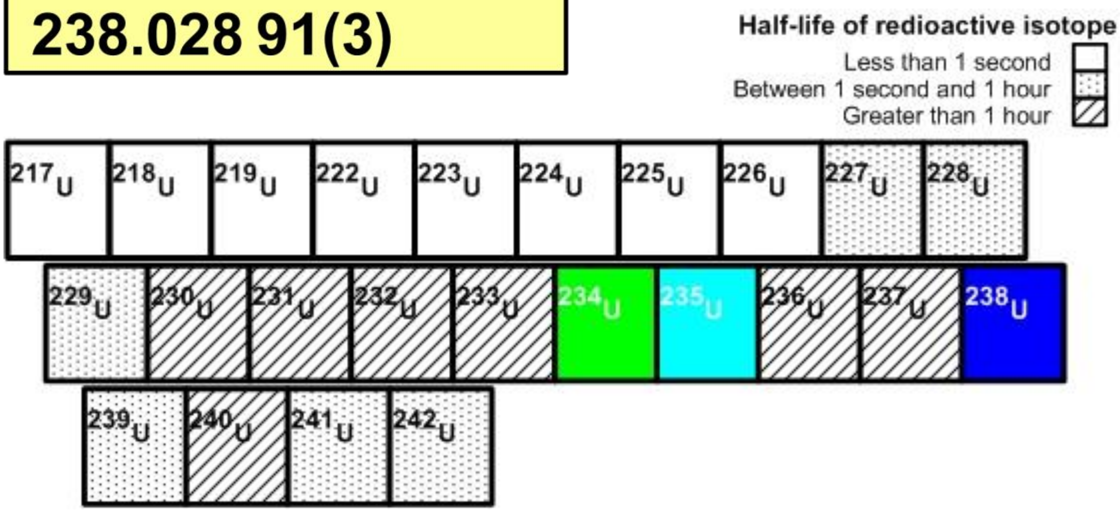
uranium



Stable isotope	Atomic mass*	Mole fraction
^{234}U	234.040 9521	0.000 054
^{235}U	235.043 9299	0.007 204
^{238}U	238.050 7882	0.992 742

* Atomic mass given in unified atomic mass units, u.



Important applications of stable and/or radioactive isotopes

Isotopes in geochronology

1) The three natural radioactive decay chains beginning with ^{238}U, ^{235}U, or ^{232}Th each have comparable half-lives, much longer than the radioactive isotopes that follow until the production of stable isotopes of ^{206}Pb, ^{207}Pb, and ^{208}Pb, respectively. Undisturbed, the activities of daughter isotopes in each decay chain are equal to their parents and one can measure the accumulation of the stable isotopes of lead to date the time that has elapsed since the mineral became a closed system. The half-life of ^{238}U is 4.47 billion years and that of ^{234}U is 246 000 years. Rocks formed 100s of millions to billions of years ago can be dated using this technique.
2) If at some point during the decay, the mineral is disturbed and isotopes in the decay chain are preferentially removed from the system, the equilibria in a decay sequence will be disturbed. For example, one could measure the excess of ^{230}Th relative to the ^{234}U parent

to date carbonate minerals (for example speolothems or corals) that are younger than 500 000 years old.

Isotopes in the nuclear industry

1) Nuclei of ^{235}U are split when bombarded by neutrons moving with "thermal" speeds. The process is known as nuclear fission and can release tremendous amounts per uranium nucleus. The nucleus that splits will release additional neutrons that, if slowed down sufficiently, can cause subsequent fission events. Properly controlled, ^{235}U fission can be used to generate heat to drive steam turbines, which in turn produces electricity. If the fission process is not controlled, a rapid and explosive release of energy will occur, such as in nuclear weapons.

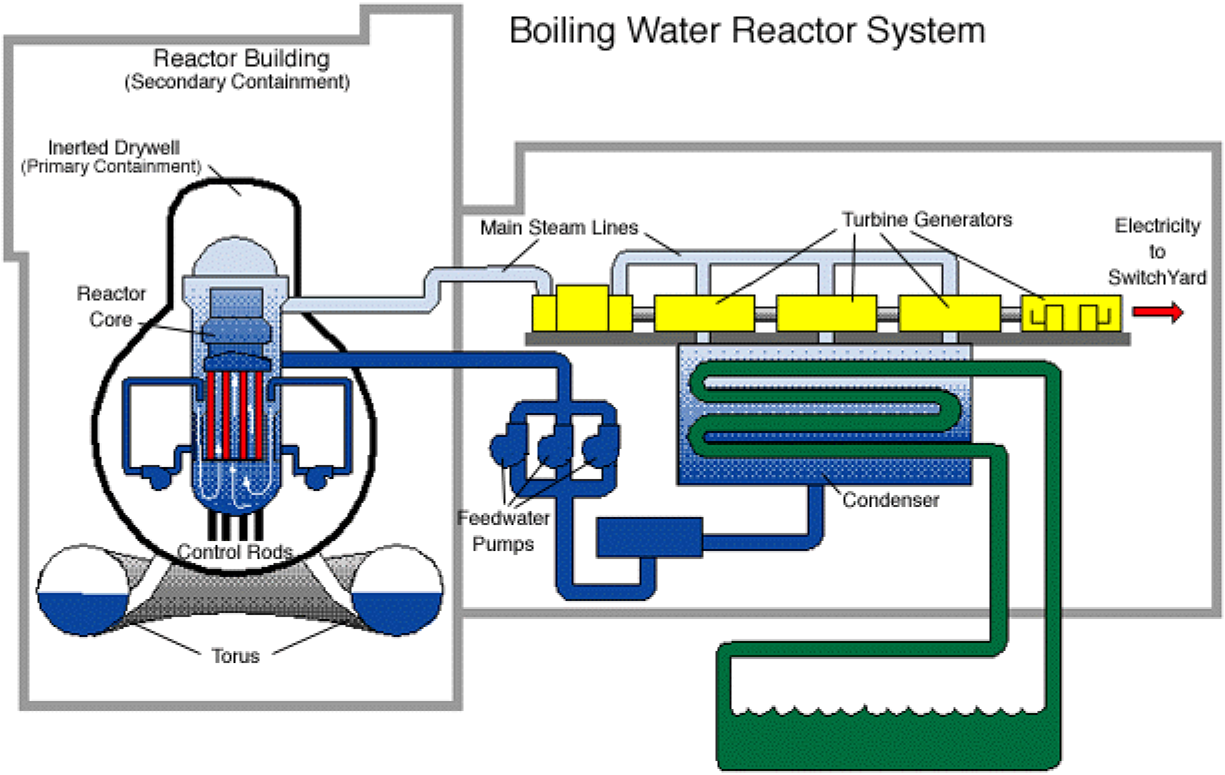


Figure 1: Boiling water reactor fuel in the above system is ^{235}U enriched as uranium dioxide.

2) ^{238}Uranium nuclei undergo fission if bombarded by "fast" neutrons, with energies greater than 1 MeV (equivalent to 1.6×10^{-13}). In a fission reactor, this is an inefficient reaction for energy production becaue few neutrons will have enough energy for ^{238}U fission. However, the ^{238}U nuclei can be used to produce ^{239}Pu as a nuclear fuel in breeder reactors.
3) Uranium depleted in ^{235}U by fission in nuclear reactors and hence greatly enriched in ^{238}U compared to "natural" uranium is used in the manufacture of DUCRETE concrete. The incorporation of the large ^{238}U nuclei makes this material an effective absorber of neutrons and gamma rays and it can be used to attenuate fluxes of neutrons and high-energy photons. The alpha particles produced by the decay of ^{238}U are effectively

absorbed by the concrete and do not pose a risk. DUCRETE is being proposed as a suitable material for the storage of radioactive waste.

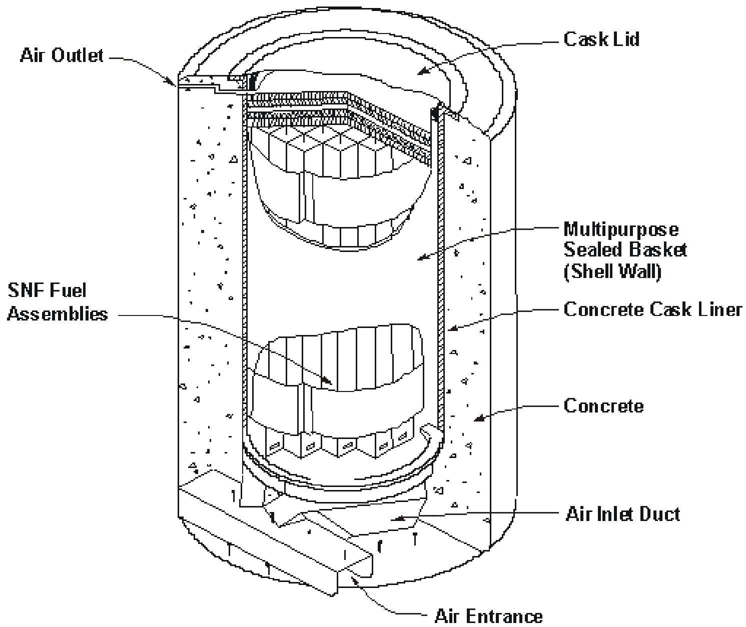


Figure 2: Ducrete cask diagram.

Isotopes in environmental studies

1) ^{234}Uranium is a daughter product of ^{238}U and makes up only 0.0055 % of the total uranium today. During the decay of the parent ^{238}U nucleus (first to ^{234}Th by alpha decay, then to ^{234}Pa by beta-minus, and finally ^{234}U by beta-minus), the energy released will damage the chemical and physical bonds holding the ^{234}U product nuclei in a mineral. As a result, ^{234}U may be leached more easily from a sample and the ^{234}U/^{238}U isotope amount ratio will vary depending on the extent of water-rock interaction.